

A PRELIMINARY INVESTIGATION OF THE NATURAL HISTORY OF THE
TIGER FLATHEAD (*NEOPLATYCEPHALUS MACRODON*) ON THE SOUTH-
EASTERN AUSTRALIAN COAST. I.

DISTRIBUTION AND SUPPLY; LENGTH STATISTICS.

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(Nine Text-figures.)

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Introduction.

Trawling in New South Wales waters has undergone many changes since its inception in the year 1915, but it is still one of the important industries of the State. Notwithstanding this fact, and the reasonable assumption that Australia offers conditions for an extension of trawling to the other States, practically nothing has been done in the way of organized scientific research on either the general or the special problems of deep sea fisheries, that is apart from the work of systematists (whose sphere is restricted in any case) and the pioneer researches of the ships '*Thetis*' and '*Endeavour*' prior to 1915.

Since 1915 a considerable amount of useful data has accumulated, mainly in the form of the records of the various companies, including the State Trawlers, and, although fragmentary in parts, could have proved of immediate practical value to those directly interested.

The scientific importance of such matters has often been urged, but neither detailed suggestive programmes of research, nor actual efforts to work out any problem have been made. In any case no money has been available, this naturally proving a rather serious deterrent. In 1927-28 the U.S.A. Government spent some £300,000 on its Bureau of Fisheries, whilst in the United Kingdom as much as £80,000 has been expended on a research vessel; in South Africa, too, £25,000 was made available for this purpose.

Early in 1930, Professor Dakin, of this Department, stressed the desirability of research in trawling problems in these waters, and suggested certain lines of inquiry and plans for investigation. The trawler companies were then complaining of a steady decline in the supply of fish in the trawling grounds.

The present investigations were initiated in 1930* and the trawling companies were approached for permission to send someone on their boats periodically with a view to making observations. Red Funnel Fisheries, Ltd., cordially invited us to make use of their ships, and our thanks are due to them for the kindness and courtesy extended throughout the work.

* The work was rendered possible by a grant from the Council for Scientific and Industrial Research, to whom separate acknowledgement must be made.

Thirteen cruises in all were made over a period of twelve months, the length of the trip varying from seven to nine days. Practically all of the present trawling grounds were visited at least once, and in some cases several visits were paid.

The tiger flathead (*Neoplatycephalus macrodon*) is by far the most important constituent of the catches, and certain aspects of its natural history constitute the subject of this paper.

During the course of the work, the writer has keenly felt the lack of time, other duties and certain additional circumstances preventing a more detailed treatment.

Acknowledgements.—I am deeply indebted to Professor Dakin, Head of this Department, who has suggested methods and lines of attack, and who has at all times maintained a keen and sympathetic interest in the work. He has, in addition, offered many helpful suggestions in the preparation of this paper; also to Captain Hales of the Red Funnel Company for making the trawlers available to us, and for assistance in many other ways. Thanks are also due to Captain C. R. Stuart and the crew of the Red Funnel Trawler '*Bar-ee-mul*' (upon which most of the cruises were made), for their ready co-operation at all times. They have been of material assistance in lessening the difficulty of working at sea. I am indebted to Captain S. Mills for indispensable assistance in the preparation of the maps of the trawling grounds, and for great help in other ways; this applies also to Mr. W. Howell, wireless operator on the '*Bar-ee-mul*'. Finally, to Mr. G. P. Whitley of the Australian Museum are my thanks due for the identification of certain fish specimens.

The N.S.W. Trawling Grounds. Text-figs. 1, 2, 2A.

Below are listed the principal areas which are worked by the N.S.W. trawlers. Brief information is given in the text and in the accompanying maps, as to the position, extent, depths, and nature of the bottom.

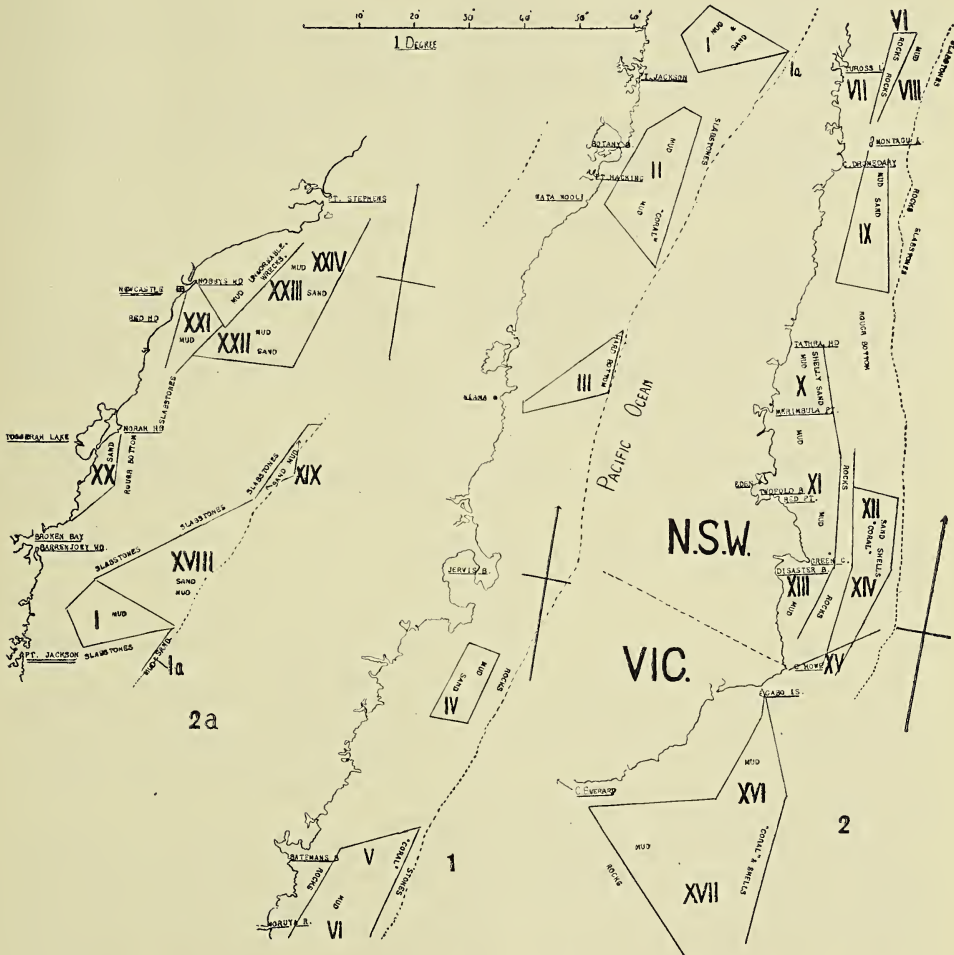
In addition to the grounds shown, there are minor areas to the north and south of the limits in the maps. Separate grounds are indicated by the Roman numerals, and it will be noticed that in some cases, one ground is merely a continuation of the one immediately contiguous thereto.

Nos. 1, 1a, and 2 are sometimes referred to collectively as the "Home grounds."

Grounds shown in Text-figs. 1 and 2.

- I. *New Zealand Close Ground.*—Depth varies from 46–65 fathoms on the western margin to 86–95 fathoms on the eastern.
- Ia. *Sydney Heads Wide.*—Depth 83–110 fathoms. This, and Nos. XVIII and XIX (Text-fig. 2A) are interesting in that they are comparatively new grounds, which are situated in deep water, and which were first tried for purely experimental purposes. For a time during 1933 they provided very good fishing, but the flathead soon disappeared.
- II. *Botany-Wata Mooli.*—Depth 32–40 fathoms to 80–87 fathoms on the eastern side.
- III. *Kiama Ground.*—Depth from 30 fathoms up to 85–99 fathoms on the eastern edge.
- IV. *Jervis Bay Ground.*—Average depth about 74 fathoms.
- V. *Tollgates-Moruya.*—Depth ranges from 22–40 fathoms along the western edge, to 75–82 fathoms towards the eastern margin.

- VI. *Pines Wide*.—A more or less direct continuation of the previous area. Depth 20–47 fathoms to 80–86 fathoms.
- VII. *Pines Close*.—A comparatively small tract of sea bottom, off Tuross Lake. Depth 20–24 fathoms.
- VIII. *North Montagu*.—Depth fairly uniform, ranging from 65 to 81 fathoms.
- IX. *South Montagu*.—Depth from 29–40 fathoms to 68–81 fathoms.
- X. *Tathra*.—Depth from 27 to 49 fathoms.



Text-fig. 1.—The grounds to the immediate south of Port Jackson. The lines marking the limits of the grounds are the actual bearings used by the trawling skippers. In this and the next two figures the dotted line to the right in the maps represents the edge of the continental shelf (100-fathom line).

Text-fig. 2.—The direct southerly continuation of Text-fig. 1. It will be noticed that the grounds actually encroach on Victorian waters.

Text-fig. 2A.—The direct northerly continuation of Text-fig. 1, showing the principal northern trawling areas.

- XI. *Eden Close*.—Depth from about 30 to 49 fathoms. Separated from XII by a narrow belt of rocks.
- XII. *Eden Wide*.—The centre of what was formerly an extremely prolific trawling area, but which has undergone considerable impoverishment during the last few years. Depth varies from 56 to 70 fathoms.
- XIII. *Disaster Bay Close*.—Depth from 24 to 45 fathoms.
- XIV. *Disaster Bay Wide*.—Separated from XIII by a belt of rocks. Depth 60–72 fathoms.
- XV. *Gabo*.—Really a continuation of XIV. Bearings at this point evidently taken from Gabo Is. Depth 55–72 fathoms.
- XVI. *Gabo North*.—The northern tip of a very extensive area of trawlable sea bottom. Depth varies from 54 to 68 fathoms.
- XVII. *Everard North West*.—A ground which is comparatively new, and which still provides an occasional good cruise. The weather here is apt to be rather uncertain, and under such conditions trawling becomes dangerous. Depth varies from 53 to 68 fathoms.

Grounds shown in Text-fig. 2A.

I. & Ia. See above.

XVIII. *New Zealand Wide*.—Depth from 76 to 104 fathoms.

XIX. *Norah Head Wide*.—Depth from 88 to 106 fathoms.

XX. *Norah Head Close*.—A ground which is now seldom visited. Formerly a recognized leatherjacket locality, enormous quantities of this fish being caught there. Average depth 27 fathoms.

XXI. *Red Head*.—Depth from 16 to 51 fathoms.

XXII. *Newcastle South*.—The southern portion of a very extensive tract of trawlable sea bottom, which also includes Nos. XXIII and XXIV. Depth 65–70 fathoms.

XXIII. *Newcastle Close*.—Depth 41–60 fathoms.

XXIV. *Newcastle Wide*.—Depth 70–74 fathoms.

SECTION I.

The Variations in the Yield of Trawled Fish from S.E. Australian Grounds during the Years 1918–22 and 1930.

In this section it is proposed to discuss the question of supply, principally in connection with the Tiger Flathead (*Neoplatycephalus macrodon*), but with some mention of the other species as well. There are indications that a considerable change has occurred since 1915, both in the quantity of fish taken and in the relative proportions of the different species.

From the commercial viewpoint, the most serious factor has been an apparent absolute decrease in the available supply, and the trawlers are compelled to go further and further afield for their hauls. The Fishing Sheets of the State Trawling Undertaking for the years 1918–22 inclusive were available and have yielded interesting data concerning the conditions of fishing, the amount of fish caught, and the localities in which operations were carried out. It has accordingly been possible to make a direct comparison with present day results.

(a) *General Conditions in the Years 1918–1923.*

The State trawlers commenced operations on the 17th May, 1915, when the two recently purchased trawlers '*Brolga*' and '*Koraaga*' left the Sydney wharf, and proceeded to a point 10 miles NNE of South Head. The nets were "shot"

in depths ranging from 50 to 68 fathoms on a bottom of mud and sand, and the following species of fish taken in numbers: tiger flathead (*Neoplatycephalus macrodon*), sharp-beaked gurnard (*Pterygotrigla polyommata*), red gurnard (*Trigla kumu*), barracouta (*Thyrsites atun*), leatherjacket (*Cantherines ayraudi*), nannygai (*Beryx affinis*) and john dory (*Zeus faber*).

The records of this and succeeding cruises were unavailable to us, unfortunately, and our records do not commence until the year 1918, so that detailed information as to conditions during the previous two and a half years cannot be given. However, during this period the boats seem to have achieved extraordinarily good results, and many heavy catches were reported. (See Roughley, p. 224.)* At the same time considerable loss seems to have been suffered through damage to fishing gear by uncharted obstructions, but this is entirely to be expected in view of the newness of the grounds.

The area of coastline exploited in these years extended from Newcastle in the north to Cape Howe in the south, although only certain circumscribed stretches of sea bottom were "worked". The grounds north of Port Jackson seem to have been on the whole considerably less prolific than those lying to the south.

Truly amazing hauls were made on the "Home Ground" (see p. 79 and Text-fig. 1) almost from the beginning, the period of heavy fishing lasting from early September until approximately the beginning of December. Occasionally the fish would remain there until the end of the latter month. Nominally the length of the cruise was 4-6 days, but in the case of the "Home Ground", catches were so huge that often the boats would return to port long before the passage of this period in order to discharge their cargo.

The predominant form in these hauls was the tiger flathead, and it was so abundant that the crews were kept on deck many hours at a time, stowing away the fish and preparing for the next haul. These flathead were described as being "very large and bursting with roe", and their excessive abundance led to the period of heavy fishing being termed the "Botany Glut". This Botany Glut became a yearly expectation, the men knowing almost to the week when the flathead would appear, and being equally certain as to the time of the "take off"; when, in 1926 and succeeding years, the customary influx failed to materialize, the vessels were compelled to depend upon other grounds for their cargoes. The "Home Ground" is now practically useless for trawling purposes, and is usually visited by the boats towards the end of the trip only, when there is still time to fit in a few hauls before going in.

On the Southern grounds, too, remarkable catches were made, particularly in the Eden-Green Cape area, and in the neighbourhood of Montagu Island (see Text-fig. 2). At the former locality, leatherjacket (*Cantherines ayraudi*) figured prominently, sometimes to the almost total exclusion of the flathead, whilst gurnard were also taken in enormous quantities. It was quite a normal occurrence to get a sequence of hauls each of which exceeded ninety or a hundred baskets, the trawl in many cases being down for sixty minutes only.

A very interesting feature of these Southern grounds was that heavy fishing might last from January till July, great quantities of flathead often being taken in the winter months, an experience which is seldom if ever enjoyed by the present

* Roughley, T. C., 1916, *The Fishes of Australia and Their Technology* (pub. by the Govt. Printer, Sydney) contains a very good account, with photographs, of the trawling methods in N.S.W. waters.

trawling fleets. There is now not only a considerable decrease in the amount of flathead taken at any period during the year, but a corresponding reduction in the quantity of "mixed fish" (in leatherjacket, gurnard, john dory, morwong, etc.). This is one of the many changes which have occurred since the prosperous years 1915-26.

A more detailed summary can be given of the yield of fish in the years 1918-22, and this will be compared with the yield for 1930.

Year 1918. (See Text-fig. 3.)

The hourly catch in hundredweights for each month of this and the two succeeding years has been set forth as a curve, the numbers representing the average of the united efforts of all the boats. However, the record is incomplete in certain cases, for some of the trawlers were "held up" from time to time, for varying periods, so that the average given represents the efforts of the reduced number of ships.

The four trawlers, '*Goonambee*', '*Goorangi*', '*Dibbiu*' and '*Dureenbee*', did not commence to fish until late in 1919 (July, August, September and October respectively) so that the figures for the first six months are those of three trawlers only, the '*Brolga*', '*Gunundaal*' and '*Koraaga*'. Furthermore, the figures for the months January, February and March of 1918 are those of the '*Koraaga*' alone. In view of the latter fact, one is not surprised to find the hourly average for the first three months of 1918 very low (1.47, 1.28, and 1.54 cwt. respectively), and when, during the succeeding months, more vessels are engaged the figures undergo considerable increase.

Incidentally it is rather clearly evident from the fishing sheets that there was a marked difference in the ability of the respective crews of these boats, though all were fishing under similar conditions. During the months of April, May and June good fishing was obtained in the Southern Grounds (Merimbula-Green Cape), all three boats concentrating their efforts in this region; an occasional cruise to the "Home Ground" revealed an almost total absence of fish. Flathead was an important constituent of all the hauls, but there was also an abundance of gurnard, skate and barracouta. Good fishing continued on the Southern Grounds until the early part of July when a considerable falling off occurred. The hourly average for June was 3.81 cwt., while for July, August and September it was in the neighbourhood of 2 cwt.

In October, the fish began to come into the "Home Ground" and this is reflected in the curve, the latter giving a good indication of the Botany Glut, for the average jumps up to 4.61 cwt., finally dropping to 3.45 cwt. in December. Very heavy fishing was encountered during this period, the main constituent of the hauls being flathead; however, gurnard were also plentiful here as on the Southern Grounds earlier in the year.

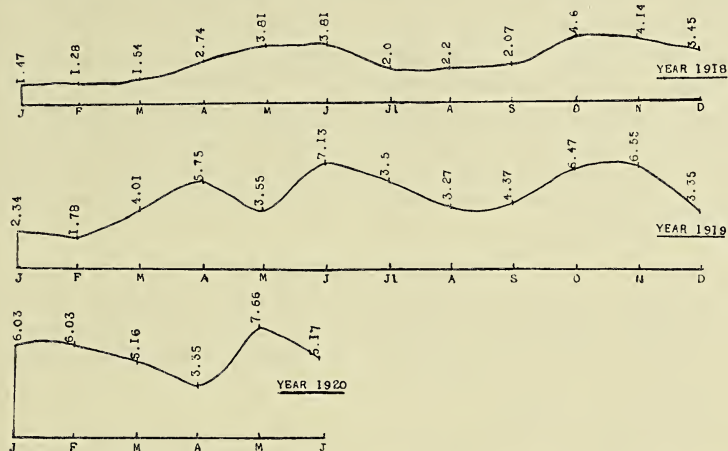
The log sheets of the '*Koraaga*' show that in one cruise (in November) hauls of 110 (2), 100 (2), 85, 70 and 60 baskets* were obtained, as well as several of fifty baskets; these figures should give some idea of the enormous amounts of fish taken during the period of the Botany Glut.

Year 1919. (Text-fig. 3.)

Conditions during this year were very similar to those of 1918. After the take off from the Botany area in December, 1918, the average shows a further

*Fifty baskets (70 lb. each) would be considered very good fishing under present conditions.

decrease for January and February of the new year (see Curve). Heavy fishing began in March and continued until the end of June. The unexpectedly low figure for May does not indicate a "take off" of fish from these grounds, but is due to the fact that the '*Brolga*' and the '*Gunundaal*' spent the greater part of the month in the "Home Grounds", where fish were decidedly scarce.



Text-fig. 3.—Curves showing the yield of flathead and other species, in cwt. per hour, for each month of the years 1918, 1919, 1920.

Once more extraordinarily large hauls were made on the Southern Grounds, a feature of interest being the fact that flathead were abundant right up till the end of June and the early part of July. Actually, however, over the whole period of heavy fishing gurnard and leatherjacket exceeded the flathead in quantity.

June, 1919, was a particularly prosperous one for the trawlers, the average hourly catch reaching the figure of 7.13 cwt. A large influx of gurnard seems to have been partly responsible, as many as 135 baskets per haul being taken. For July and August, the figures are low (see Curve), but in September and October the Botany Glut begins to manifest itself and once more the average undergoes a rapid increase. Just as in the previous year, the fish had disappeared from the Botany area by the end of November, so that for December the curve sinks to its previous low level.

Year 1920. (Text-fig. 3.)

This year must have been a very interesting one from the viewpoint of fishing, and it is most unfortunate that the records for the first half only of the year were available to us. Of great interest is the fact that during the first half of January there was apparently a secondary influx of flathead into the Botany area, for two of the boats at least ('*Brolga*' and '*Koraaga*') obtained very heavy fishing here at this time, flathead being the predominant constituent of the hauls.

The hourly average for the month January, 1920, is 6.03 cwt., a marked contrast to the 3.35 cwt. of the previous month. In January also, heavy fishing commenced in the Southern Grounds and continued until the end of June at least, the available records only extending to this point. With the exception of

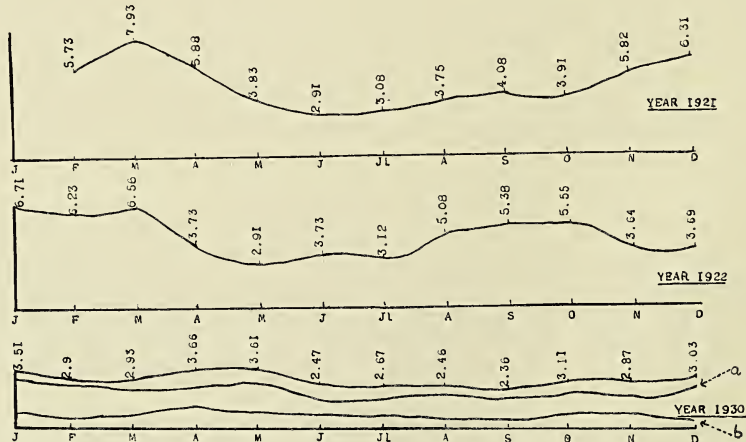
April (3.35 cwt.) the hourly average remains high, reaching no less than 7.66 cwt. in May. The low figure for April is due to two causes: (a) a temporary "take off" of the fish from the area of heavy fishing, and (b) most of the boats visited other grounds where fishing was very poor.

Another fact of significance which emerges from these records is that concerning the relative proportions of the three principal species taken (flathead, gurnard and leatherjacket) during the period of abundance. At the beginning of May (the "peak month" for 1920) leatherjacket was by far the most plentiful species present, but the numbers underwent a gradual decrease until flathead occupied first position. In the meantime, coincident with the decrease in leatherjacket, an influx of gurnard had been taking place, the latter eventually ousting the flathead from the first position, so that finally the original relations were completely reversed, gurnard being predominant, flathead next, and leatherjacket an insignificant third.

Year 1921. (Text-fig. 4.)

The log sheets of the trawlers '*Gunundaal*' and '*Koraaga*' for 1921 were unavailable, and in addition to this the writer was unable to get any record of the January hauls of any of the boats. The hourly averages for the months of 1921 are consequently based on the operations of five boats instead of seven, and data for January are lacking.

As in previous years, a great influx of fish occurred in the Southern Grounds, but this time the peak month is March, with the remarkable hourly return of 7.93 cwt. Flathead was by far the predominant constituent of the hauls, and it was during this "peak month" that the '*Brolga*', under the command of Captain C. R. Stuart, made what was claimed to be a world's record. Seventy-eight thousand one hundred pounds of fish were trawled in eight hauls of 1 hour 40 minutes duration each, or 14 hours in all. All the fishing was done off Green Cape, 90% of the catch was flathead and the hauls in succession were 150, 140, 142, 154, 137, 132, 125 and 124 baskets.



Text-fig. 4.—Curves showing the yield of flathead and other species, for the years 1921, 1922 and 1930. In addition the 1930 curves for flathead (a) and for the remaining species (b) are given separately.

After March, considerable decrease occurred in the amount of flathead, which was largely replaced by leatherjacket and gurnard. Of interest, too, is evidence of a considerable temporary influx of leatherjacket and gurnard into the Botany Area in May, this being a rather unusual happening. After April and May (5.88 cwt. and 3.83 cwt. respectively) the fish appear to have "taken off" from the Southern Grounds. In the latter part of July and during August, however, there appears to have been much flathead in the neighbourhood of Montagu Island, for certain of the trawlers, notably the '*Brolga*', secured some very good catches. The hauls were not large, but remained consistently good.

This year the "Botany Glut" period was not nearly so pronounced as in previous years, and although rather large hauls were made, the averages for September, October and November were distinctly lower than those for the corresponding period of 1919. During the months of November and December some of the boats visited the Montagu Island area and experienced very heavy fishing. Flathead were so abundant that all the remaining species were dumped overboard, in order to conserve space. The '*Brolga*' in particular made several extraordinarily good cruises to this area, and the results are reflected in the high figures for November and December (5.82 and 6.31 cwt. respectively).

Year 1922. (Text-fig. 4.)

The record for this year is almost entirely complete, since all seven boats were engaged in active fishing operations, although log sheets are lacking for certain of the months in some cases.

The year 1922 is interesting chiefly because of the early influx of fish into the Southern area, this apparently having been well under way during the latter part of December, 1921. The period of heavy fishing shows a marked backward displacement as a whole, being restricted almost entirely to the first three months. The figures for these are accordingly high, being 6.71, 6.23 and 6.56 cwt. respectively. Although flathead were abundant, leatherjacket seem to have been the predominant form by far, numerous heavy hauls being secured.

After March, the averages are low until August, when the usual influx of flathead into the Montagu Island area seems to have occurred. The average hourly catch for August is 5.08 cwt. Towards the end of September, the period of the Botany Glut commenced, and this time, perhaps more than any other, extraordinarily heavy fishing prevailed. Thus in eight successive cruises to the "Home Ground" the '*Brolga*' caught 56,700, 82,300, 52,400, 62,700, 45,200, 46,000, 61,900 and 45,900 lb. of fish, the bulk of this being flathead. The greatest amount (82,300 lb.) was caught in 41 hours actual fishing time. In October the '*Brolga*' also paid one visit to the Montagu Island area with very profitable results, the return for 46 hours fishing being 47,500 lb. This was almost entirely composed of flathead. During November and December the fish seem to have moved away from the Botany area for the catches show a marked decrease.

This year, too, in late November and early December certain of the boats visited Montagu Island and experienced heavy fishing, large hauls of flathead being taken. It is difficult to state whether the influx of flathead into this area occurred in the latter part of November, or whether they had been in the locality since August, since during the intervening months fishing operations were concentrated on the grounds in the neighbourhood of Sydney. It is a significant fact that flathead were found in great quantity off Montagu Island in October (see Curve), and furthermore another trawler (the '*Dibbinu*') had been experiencing

heavy fishing (flathead) in neighbouring areas up till the middle of September. It is possible that undue attention has been focussed on the occurrence of heavy fishing in the Botany area, and that the influx of fish into the latter may merely have been part of a general movement inwards towards a much larger tract of coast, extending as far south as Montagu Island at least. The trawlers would naturally find it much more convenient to confine their operations to local grounds, and thus would be created a false impression as to the amount of fish available in other parts.

Discussion of Results, 1919-1922.

A striking fact which emerges from the foregoing is the general high level maintained by the hauls throughout the greater part of the year. With the exception of about three months, there seems to have been a comparatively abundant supply of fish available during the year on the various grounds. During the months of September, October and November, the Botany Glut prevailed, and when this came to an end, the ships moved further south to the Merimbula-Green Cape area. In the latter locality heavy fishing was sometimes experienced up till the end of June, even flathead being taken in quantity at this late period. In August, flathead seems to have been abundant in the region of Montagu Island. The curves drawn for the years 1918-22 inclusive exhibit the results (Text-figs. 3 and 4).

TABLE I.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1918	1.47	1.28	1.54	2.74	3.81	3.81	2.0	2.2	2.07	4.61	4.14	3.45
1919	2.34	1.78	4.01	5.75	3.55	7.13	3.5	3.27	4.37	6.47	6.55	3.35
1920	6.03	6.03	5.16	3.35	7.66	5.17						
1921	—	5.73	7.93	5.88	3.83	2.91	3.08	3.75	4.08	3.91	5.82	6.31
1922	6.71	6.23	6.56	3.73	2.91	3.73	3.12	5.08	5.38	5.55	3.64	3.69
1930—												
(a)	3.51	2.9	2.93	3.66	3.61	2.47	2.67	2.46	2.36	3.11	2.87	3.03
(b)	3.03	2.57	2.26	2.49	2.92	1.75	2.0	2.02	1.89	2.39	2.0	2.56

(a) All species included.

(b) Flathead only.

Hourly catch of fish in cwt. for the years 1918-1922 and 1930. These figures were used for the construction of the curves in Text-figs. 3 and 4.

The curve for each year shows two fairly well defined maxima, corresponding respectively to the "Botany Glut" period (September-November), and to the period of heavy fishing in the Southern grounds. But when one compares the curves year for year, certain differences are at once evident. It is found that the fish do not always become abundant at exactly the same period each year, this being especially the case in the Southern grounds. With the latter, indeed, a considerable amount of variation seems to be the rule. Thus, in 1918, heavy fishing did not commence there until March, rose steadily until June, and then fell to its previous level in July, lasting for a period of about four months. In 1919, the period of heavy fishing extended from February to July, whilst in 1920, although records were only available for the first six months, there is indication that the period of abundance commenced in January, there being a considerable falling off at the end of June.

In 1921 a restriction is indicated to the months February-May inclusive, whilst in 1922 there is evidence that fish had become scarce after the first three months.

Taken together, then, these results show a tendency for a backward movement of the period of abundance towards the early part of the year. It is impossible to say whether this variation was a normal feature of the area or whether it was an expression of a change wrought by the continued intensive fishing operations, a change which has ultimately led to the present general scarcity.

A point of some importance, to be decided, is the degree of reliability of these fishing records. In other words, do they present a true picture of conditions prevailing on the sea bottom at the time? The actual state of affairs might be given an altogether different guise, by the interposition of such artificial factors as variable ability on the part of the respective skippers, and the number of cruises made to an area throughout the year. As a matter of fact, there seems to have been an extraordinary variation in the efficiency of the different crews or gear, some vessels regularly returning with much higher catches than certain of the others, even though all were working over the same ground. In addition, considerable loss seems to have been experienced through the use of faulty equipment and the inability of the crews in certain cases to restore the latter to efficient working order. But these factors would tend on the whole to decrease the total amount of fish captured during the year.

Now, regarding the other factor mentioned, viz., the number of cruises made to any particular ground throughout the year, there is much room for misconception. Thus, in the curve for 1919 there is a sudden drop from a high level in the month of May. On the face of it, this might be read as a sudden "take off" of fish from the Southern grounds at this time, whereas it is really nothing of the sort. An examination of the fishing records reveals the fact that during May, 1919, the boats confined most of their operations to the Home Grounds near Sydney, even though the fishing there was very poor. The few cruises which were made to the Southern Grounds during this month showed that the fish were just as abundant there as they had been during the previous month. A similar case is presented by the hourly average for April, 1920.

However, allowing for these factors where necessary, it is considered that the results give a reasonably reliable guide to the conditions actually prevailing. When one considers the hourly average for the whole year, all boats included, it is seen that there is a definite increase during the period 1918-22 (see Text-fig. 5). For 1918 the average is 2.9 cwt. and for 1919, 4.18 cwt. As the records for the first half only of 1920 were available, the figure 5.56 cwt. may be safely taken as being too high, the period covered being normally one of heavy fishing. For 1921 the average is 4.56 cwt., whilst in 1922 it rises to 4.68 cwt. At this point, unfortunately, the record ceases. It is not suggested that these figures are evidence for an actual increase of available supply, and probably do little else but indicate increased efficiency on the part of those engaged in trawling operations.

As stated elsewhere, the period of plentiful supply is reported to have ceased in 1926, and according to those engaged in trawling, the decrease has become more marked each year. The fishing records of one company for the year 1930 have been made available to us, and these will serve as a basis for comparison. Unfortunately the actual form of the fishing sheet has undergone considerable modification since 1923, and now contains far less useful information than did its predecessor, so that it is not possible to treat the results in the same full

manner. In any case it has been our experience that the skippers dislike filling in any but the barest essentials, and leave gaps elsewhere.

Year 1930. (Text-fig. 4.)

An outstanding feature of the 1930 results is the general small size of the hauls. The remarkable figures of 1918-23 are seldom, if ever, reproduced, and even forty baskets per three-hour tow is considered unusually good fishing.

The trawler '*Millimul*' had two good cruises in January, returning with 692 and 675 baskets of flathead on these respective occasions. The bulk of the operations were conducted in the Eden-Green Cape area. But we find that the times taken to catch these quantities were considerably longer than would have been the case during 1918-23. Thus on the first cruise the actual fishing time was 114½ hours, whilst on the second it was 69½ hours.

A further fact of interest is the decrease in the relative quantities of flathead and "mixed fish" taken. For the year 1930, the proportion was 5:3 : 1, and, whilst no definite figures can be given for the years 1918-23 (since such information was not included in the fishing sheets), the relative amount of "mixed fish" (i.e., gurnard, leatherjacket, skate, morwong, etc.) seems to have been considerably greater. During the period of heavy fishing on the Southern grounds during these years, flathead quite frequently occupied a minor place in the hauls, the bulk being made up of leatherjacket and gurnard with smaller quantities of skate, john dory and barracouta. Nowadays the reverse is usually the case, and very seldom do these species exceed the flathead in point of number.

This falling off in the amount of "mixed" is not one of the least important changes which have occurred during the later years of the industry. The average hourly catch for the year 1930 was 2.97 cwt. only, a marked decrease compared with the figures for 1921 and 1922, viz., 4.56 and 4.68 cwt. respectively. It has already been seen that the average for 1918 was 2.9 cwt., but this only indicates that the topography of the grounds and the movements of the fish were still imperfectly known. The falling off in supply is even greater than the figures indicate, for present fishing operations are conducted with much increased efficiency, and an improved form of otter trawl is in use.

Text-fig. 4 gives the average hourly catch for each month of 1930. It takes a very different form as compared with corresponding curves for the years 1918-22. The hourly average for January is 3.51 cwt., but there is a decided fall in the next two months (2.9 and 2.93 cwt.). In April the maximum occurs (3.66 cwt. per hour), this figure being almost reached in May (3.61 cwt.). Thereafter the level remains generally low until October, when it again rises, reaching 3.11 cwt. In November a drop occurs to 2.87 cwt. and in December the average rises to 3.03 cwt. This curve represents the hourly catches of flathead and other species combined, and further information may be deduced by considering these separately.

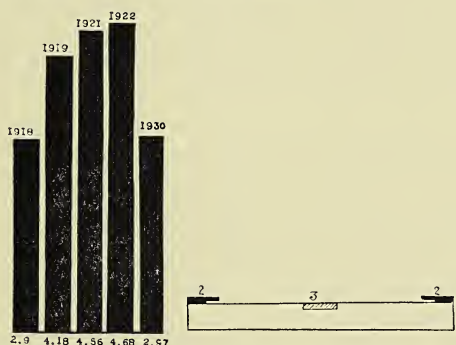
The flathead maximum occurs in January with 3.03 cwt. per hour. After this there is a general tendency (with, however, minor fluctuations) for a decline until the end of September (1.89 cwt.), when an increase once more manifests itself, the returns for the last three months of the year being 2.39, 2.00 and 2.56 cwt. per hour respectively. The curve for the remaining species, all grouped together as "mixed", is rather different in that it exhibits its maximum three months later than the flathead curve, and undergoes relatively large fluctuations throughout the year.

Perhaps the most striking feature of the 1930 curve for all species, flathead included, apart from the general low level of the catches, is its "flatness" when compared with corresponding curves for, say, 1921 or 1922. This is due to the almost entire disappearance of fish from the Botany area, and the considerable falling off in supply on the Southern grounds. On this account the well marked "peak" commencing about September has practically disappeared, whilst the other one for the January-June period has also become much decreased in magnitude. The small rise in October and November is due to the fairly good fishing obtained off Newcastle during these months, whilst the comparatively high figures for the first five months of the year are the result of successful operations conducted in the Southern grounds. Of the latter the comparatively new Cape Everard area bulks prominently in importance. It is possible that the January maximum in the curve for flathead only is closely connected with the breeding period of the fish in the Southern grounds. During the corresponding period of 1931 the writer had the good fortune to visit these grounds and most of the flathead taken were females with the ovaries in an advanced state of development.

SECTION II.

Length Statistics.

Length measurements of the flathead, as they occurred in the hauls, were conducted with several objects in view. Firstly, it is well known that if taken over a sufficiently long period at different seasons and without artificial selection of the samples they may present a picture of size classes which may be used for the determination of age. The distribution of size classes can be used for the discovery of migratory movements of the fish and, finally, comparative treatments of length measurements may give valuable information regarding overfishing. This is actually the first of our fishing investigations on the coast of Australia, and it must be regarded as a preliminary study.



Text-fig. 5.—Comparison of yields of flathead in cwt. per hour's fishing, for the years 1918, 1919, 1921, 1922 and 1930. For further information see text.

Text-fig. 6.—Section across measuring board. 1, board; 2, guides; 3, metre rule let into board.

The measurements of some 35,000 flathead were taken over a series of monthly cruises, the period ranging from March, 1930, to April, 1931, and over an area of coast extending from Port Stephens to Cape Everard (see map). Unfortunately it has not been possible to follow up the work at sea owing to other duties; consequently a comparison of any particular period with a corresponding period

during the following years cannot be made. The evidence obtained within the twelve months is again rather fragmentary in that the same fishing ground was seldom visited on two successive monthly cruises. There are, however, compensations, for had attention been focussed on one or two areas only, then the other grounds with their different conditions would not have been seen at all.

An extensive system of body proportion measurements had been planned, but owing to lack of time and the difficulty of working conditions, was not put into operation. It was here that the need for an assistant was most keenly felt, for the data obtained from such observations are of major importance in determining growth rates and racial differences. It must be recognized that the work was carried out whilst the author was really a guest on a commercial trawler. No interference with the working of the boat could therefore be thought of.

With the aid of suggestions from Professor Dakin, the actual length measurements were rendered extremely simple, the operations requiring the attention of one person only. The apparatus (which was based on a method suggested by Buchanan-Wollaston) cost considerably less than five shillings to construct, and has proved accurate and effective in practice. It consists of a rectangular piece of board 120 cm. in length and some 10 cm. in width, into the upper surface of which has been let an ordinary metre rule (graduated on one edge into centimetres and millimetres, and on the other into inches and tenths). At one end of the board, and corresponding exactly with the zero of the rule, a small piece of wood is screwed to act as a stop, whilst running along each side of the board throughout its length are two narrow celluloid strips slightly raised from the surface. These serve to hold in position the large strip of celluloid used for recording the actual measurements, the strip sliding in underneath (see Text-fig. 6). When making measurements the celluloid strip is placed in position, a flathead placed on top with its snout up against the wooden stop and the slightly concave margin of the caudal fin spread out. A mark is then made in the celluloid by means of a small awl at a point corresponding to the centre of the margin of the expanded tail. In this manner an accurate and indelible record of the length is made and after a time a remarkable speed can be attained by the operator. Such rapidity is achieved mainly by the elimination of waste movements, and exactness is not sacrificed.

Something like 800-1,000 lengths were recorded in one strip of celluloid, the difficulty of the awl going into the same hole twice being practically non-existent. Upon return to land, the measurements were read off comfortably in the laboratory, using another board similar to the one already described, but which lacked the side guides. The process of reading off also proved quite simple, it being possible to read and enter some three thousand measurements in a book in less than an hour and a half.

Readings were always taken to the nearest centimetre above, and were made by means of a metal slide having a slit exactly 1 cm. wide. This slide was moved from figure to figure along the scale (visible through the celluloid strip), the number of stabs between the slide gap being counted. Some 35,000 fish were measured during a series of thirteen cruises, the highest number for any individual cruise being more than 5,600, and the lowest somewhat more than 1,000.

The Relation of Length to Age.

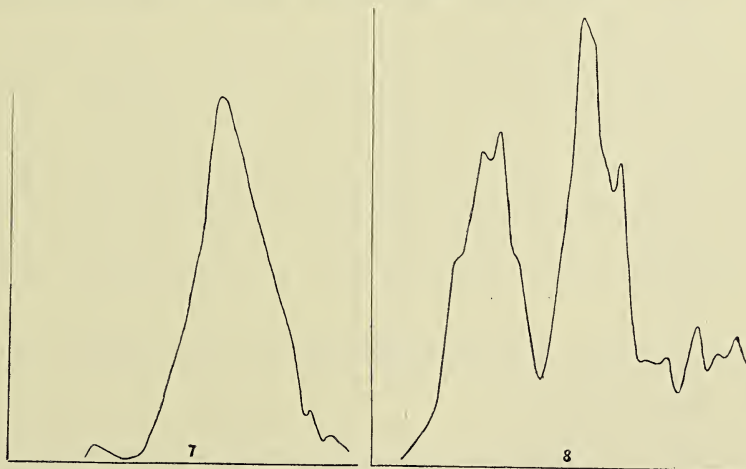
Investigators of fisheries problems in the Northern Hemisphere have been particularly fortunate where age determination of fish is concerned, for a variety

of methods is available. This fact is due in part to a marked discrepancy in the summer and winter growth rates of the fish, this difference finding expression in important structural details in such parts of the body as the scales, otoliths, opercular bones, and vertebrae. All these, when examined under suitable conditions, exhibit well marked growth bands of varying width according to the kind of season passed through, so that it has not only been possible to arrive at a very close correlation between these bands and the age of the fish, but also information has been adduced regarding the general conditions of the environment during preceding years. The length determinations constitute an important complement to these observations, since they not only provide a check for the age computations, but also furnish data regarding the distribution of sizes and the migratory movements of the fish.

This section of the work was approached by us with considerable interest, for apart from the newness of the field, the question of the applicability of the research methods of temperate waters to a sub-tropical region was one of much moment.

On the first cruise 1,230 flathead were measured. The smallness of this number was due to lack of familiarity with working conditions and lack of suitable apparatus. The type finally adopted, which is described elsewhere, was not constructed until after the writer's return from this initial cruise. Of the measurements, some 769 were made on the Cape Everard ground, 275 at Eden, and 186 at Wata Mooli. The curves based on the two latter series show considerable irregularity, presumably owing to the small number of specimens on which they are constructed, yet have points of resemblance to the curve drawn from the data obtained at Cape Everard. The latter curve exhibits a single decided "peak" at 42 cm., falling away steeply on either side of this point (see Text-fig. 7).

On the following cruise two more sets of measurements were made, at Eden and Cape Everard respectively, and each curve conformed to the type obtained in the first cruise, i.e., one with its maximum at 42 cm. The Eden curve, however, showed indications of a second smaller "peak" at 31 cm.



Text-fig. 7.—Curve based on measurements made at Cape Everard. Maximum at 42 cm.

Text-fig. 8.—Curve based on measurements made at Wata Mooli. Maxima at 24 and 32 cm.

The similarity of all these curves was very interesting, since it gave possible indications of the fact that the fish moved about in size groups, and that this particular one (in the 42 cm. group) predominated on the Eden and Everard grounds. At this stage it was not possible to say whether or not a definite segregation into age groups was indicated, although it seemed very probable that such was the case. Subsequent results have served to strengthen this conviction.

On succeeding cruises further curves were obtained with peaks at the 42 cm. mark, but showed in many cases equally well defined peaks at other definite points. These points were not exactly the same in every case, extending as they did over a range of some five centimetres, yet for any particular type of curve the maximum was sufficiently constant to justify the assumption that it really represented an age group. The complete results are set forth in tabular form in Table 2, and it is seen that there are four well defined size groups.

The first of these is represented by fish 24 cm. in length, and the second by fish of 30-36 cm. with a tendency to a predominance at 31-33 cm. The third group is very well defined, being represented mainly by fish of 42 cm., the range being 41-44 cm., whilst the fourth one is occupied by flathead of length 54 cm.

Of these four groups the first and the last are based each on one set of measurements only, but as the number of specimens measured in each case was reasonably large, 1,380 and 1,185 respectively, their true nature seems fairly well established. Of the other two groups, the second has occurred nine times and the third twelve times. On certain occasions a curve showing two peaks has been obtained, one embracing members of the second group and the other those of the third group. In the case of the Group I curve (see Text-fig. 8) there was also another even larger peak corresponding to Group II, and further signs of a third one at Group III (41-44 cm.), although the small number of specimens of larger sizes rendered the curve very irregular at this point. On same cruise a typical Group III curve also obtained. Now, from the viewpoint of age determination there are certain serious deficiencies in these results. Firstly, flathead less than 15 cm. in length were not taken in numbers whilst the writer was present, so that data regarding the sizes from 1 to 20 cm. are entirely lacking. This means that it will be very difficult indeed in our present state of knowledge to assign to Group I its true position in an age scheme. Some data may possibly be afforded by scale readings, but it is very essential to obtain some information as to the rate of growth of flathead during their young stages. Although in almost every case each curve has been based on measurements from one area only, different curves come from different localities, so that the question of racial distinction must be taken into account. It is quite conceivable that the growth rate would not be the same in any two given races, and a "lumping together" of all the results, regardless of this factor, might introduce considerable error.

Just how far the races (if present) differ in their growth rates it is impossible to say, for this line of research is as yet undeveloped, and incidentally is of the greatest importance.

Up to date our figures indicate that the tiger-flathead from the Green Cape area, for instance, are similar to those from, say, Botany, some 320 miles further north, insofar as body proportions are concerned. It is, of course, always possible that a length group from fish of an extreme northern locality might be of different age from those falling within the same group at another locality.

TABLE 2.

Locality.	No. of Specimens Measured.	Lengths in Cm.																					
		22-23	24	25-29	30	31	32	33	34	35	36	37-39	40	41	42	43	44	45	46	47	48-53	54	55-60
O. Everard..	769												X—	X									
Tathra-Eden	813													X									
C. Everard	2045													X									
Eden ..	2983													X									
Eden ..	1864						X							X									
Green Cape	506						X							X—									
C. Everard	1617													X—	X								
Moriya ..	5771													X									
Montagu ..	1008													X									
Wata Mooli	1380						X																
Newcastle ..	1185																						
Pt. Stephens	1198																						
Pines-Montagu	1945																						
Merimbula - Green																							
Cape ..	2337																						
Merimbula-Eden..	1151					X—								X									
Jervis Bay	1142				X—	X									X								
New Zealand Ground	1058																						

Particulars of the principal series of measurements, including locality, number of specimens, and point of the maximum of the curve in each case. The sign X indicates the position of the maximum, and when the latter extends over a range this is indicated by a crossbar, with an X at either end.

Bearing in mind these considerations, the following facts appear to be established. The curves when taken together to form a composite show four marked peaks (Text-fig. 9) and these conceivably correspond with four age groups. As already indicated, data regarding the 1-20 cm. flathead are lacking, and until this deficiency is remedied, one cannot go much further. It is an interesting fact that the intervals between the "peaks" are approximately equal,



Text-fig. 9.—Composite curve based on measurements from different localities, and showing the possible occurrence of age groups in the flathead. The maxima are at 24, 32, 42 and 54 cm. respectively.

being of the order of 8-10 cm. This constancy is of considerable significance and is conceivably evidence for a uniform growth rate and a uniform spacing of the breeding seasons. The latter seems more or less established already, but there is no certainty about the former.

The more abundant group throughout the whole period spent at sea has been the 42 cm. one. This could mean that the year in which they were hatched was a very favourable one for survival, and that the present abundance is a direct reflection of this. It is much to be regretted that length statistics were not continued for another year at least, for presumably such investigations would furnish data regarding the rate of growth.

Under present limitations we are debarred from utilizing an extremely useful method of attack for this problem, viz., liberating large numbers of marked fish and keeping a careful record of time and place of recapture, together with any increment in size which has occurred in the meantime. It would be impossible to conduct such operations unless arrangements for special cruises were made. The trawl would need to be used differently, and plenty of time would be necessary. At present the obvious aim of the trawler is to catch as much fish in the shortest possible time, and few, if any, of the flathead are in a suitable condition for reliberation after a three or four hour trawl.

There is some indication that certain age groups may remain in the same locality for long periods. Thus the curves based on measurements of Cape Everard flathead were always alike in character, exhibiting the single large "peak" at 42 cm., whilst measurements made in the shallow water (30-35 fathoms) off Eden showed a far higher proportion of smaller sizes than did corresponding series from deep water (60-65 fathoms) in the same locality. This tendency for a particular size of flathead to remain on the same ground for long periods has been known to the trawler men for years, and they described it to the author by saying, for instance, that "you get a different class of flathead at Eden from the one at Newcastle". Incidentally, in connection with the latter locality, the prevailing belief is that the flathead taken there are always very large. When the writer paid his one and only visit there in November, 1930, the average size was decidedly high, so much so that the curve showed its maximum at the 54 cm. mark. However, the Newcastle area is only visited for a few weeks towards the end of each year when the fishing becomes good, and it is impossible to say whether the average size remains high throughout the year.

Large flathead are also supposed to be the rule at Botany and on the New Zealand ground, but this is not always so. For instance, in September, 1930, there occurred an amazing influx of very small flathead into the Botany area. This is reflected in the curve (see Text-fig. 8) which has two peaks, one at 24 cm. and the other at 32 cm. Beyond the latter point, the curve "flattens out" considerably, indicating a relative scarcity of the larger sizes.

The length determination on another occasion provided important confirmation of a major migratory movement connected with the breeding season. In August 1930, a cruise was made to the Moruya-Tollgate area, where an extensive series (5,771) of measurements was made. The curve based on these confirmed the observation that small flathead, i.e., less than 40 cm., were in the majority, being present to the extent of 61% of the total. The larger flathead with developing ovaries were thus by no means plentiful. On the following cruise (late September), however, which was also made to this ground, a marked change was observed to have occurred. The curve showed that the average size had gone up very considerably, fish of less than 40 cm. now being present to the extent of 14% only of the total. Large numbers of females with ovaries in an advanced state of development were taken each haul, and it was obvious that oviposition would occur in a relatively short time. The increase in average size was such as would be noticed even by a casual observer, but it was interesting to obtain such exact and striking confirmation of the fact. Further mention of this event will be made in a paper on the breeding habits and food of the tiger flathead.

GENERAL SUMMARY AND DISCUSSION.

Comparison of fishing statistics of the years 1918-23 with those of 1930 has revealed a considerable falling off in the hourly yield of flathead. This falling off has been particularly noticeable on the grounds near Sydney, and is also marked in the other areas exploited. The trawling industry has been considerably affected thereby.

Extensive length measurements of the tiger flathead have been made on trawlers over a period of twelve months, and from many localities. These measurements have served to demonstrate the possible occurrence of "age groups" in the flathead. A composite curve has been drawn and shows four well defined "peaks" separated by approximately equal intervals. The curve is incomplete in that data regarding flathead from 1-20 cm. length are lacking.

The minimum lawful size for marketable flathead is twelve inches, and our measurements show that the flathead caught by the trawlers belong to ages extending over a period of probably four years, as indicated by the four peaks on the composite curve. If the first peak corresponds to an age of 'x' years, then the ages of the succeeding groups of these commercially valuable fish are $x+1$, $x+2$ and $x+3$ years respectively.

The importance of the results from the measurements lies in their use for purposes of comparison. The majority of flathead caught in 1930 fall into the 42 cm. group, but in future years it may be found that the group above or the one below is the predominant one. Such a situation would permit of certain definite deductions regarding migration or overfishing.

A series of curves taken at different times in the same locality reveal the tendency for an age group to remain on the same ground for long periods. The curves also reveal a tendency for the fish to shift about in age groups and have, in two cases, served to provide a pictorial record of important migratory movements, but owing to the shortness of the period investigated do not furnish immediately conclusive data regarding overfishing (see above). The latter has often been quoted as one of the prime causes for the present scarcity, and such a view may have some justification, seeing that we have been removing fish from our coastal waters at an enormous rate.

To quote Dakin (1931): "The present New South Wales grounds all added together are only equal to about two-thirds of the Irish Sea—the area of water between Ireland and England, and this from the point of view of steam trawling is nothing more than a huge lake. Discussions are frequent in Europe on the impoverishment of the Irish Sea and North Sea. Well, we have removed from our coastal area by trawling alone four times the catch that the Irish Sea has provided in the same time with its far more boats and men. In 1927, 10,763,600 lb. of fish were trawled from New South Wales waters, to say nothing of the huge estuarine catch."

If, however, overfishing has not been the prime cause and the tiger flathead have, for instance, moved to less disturbed localities, one is led to inquire where they may still be found. It has been suggested, in the face of considerable opposition, that the deeper waters off our coast, i.e., beyond the 100-fathom line, may prove of much importance in the future development of the industry. Unfortunately, evidence on this point is extremely meagre, but the few experiments which have been carried out have produced decidedly interesting results, and it is considered that further research along these lines is desirable. The field is a very extensive one, for apart from our comparative ignorance of the ocean currents, accurate information on the subjects of depths and the nature of the bottom is also lacking.

Experiments on the possibilities of the deeper waters have been very few on account of lack of adequate equipment and also of the necessary finance. In 1920 the Government trawler 'Gunundaal', under the command of Captain J. Forder, made a few hauls in depths ranging from 100 to 170 fathoms at a station some 15-18 miles NW/W of South Head, on a sandy bottom. The net was drawn for a total period of $39\frac{1}{4}$ hours and 4,960 lb. of edible fish were taken. The principal species caught were the same as those which occur in shallower waters, viz., cucumber fish (*Chlorophthalmus nigripinnis*), sawfish (*Pristophorus cirratus*), skate, leatherjacket, john dory, morwong and "flathead". Apparently the term flathead applies in part at least to the deep sea flathead (*Hoplichthys haswelli*).

This beginning, though small, was at least promising, but the experiments were discontinued. Other isolated attempts in recent years have been made to test the possibilities of these deep sea grounds, and they too, although providing interesting results, were not followed up. In the year 1928 a few hauls were made in the deep water off Sydney Heads by one of the privately-owned trawlers. One "tow" of one hour's duration produced no less than one hundred baskets of cucumber fish (*Chlorophthalmus nigripinnis*), one of the choicest edible fish taken by the trawlers, yet usually discarded because of comparatively poor keeping qualities. Taken together, these results, meagre though they be, show that the deeper waters have distinct possibilities as trawling areas, and their fuller investigation should yield data of much importance in the future development of the industry.

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